CLAIMS

What is claimed is:

1. A method for rendering a graphical object, the method comprising:

defining a bump map to describe a bump mapped surface on a three-dimensional graphical object; and

defining a horizon map for the bump mapped surface in a plurality of color channels of a set of texture maps.

2. The method as defined in Claim 1, further comprising:

defining light having a direction relative to the bump mapped surface;

interpolating from the horizon map relative to the direction of light to determine those portions of the bump mapped surface that are:

lit by the defined light; and

in a shadow cast by a bump of the bump mapped surface;

rendering, from a given point of view, the lit portions of the bump mapped surface.

3. The method as defined in Claim 2, further comprising:

interactively receiving instructions that change the direction of light relative to the bump mapped surface;

repeating the interpolating using the changed direction of light; and

repeating the rendering using the changed direction of light to render lit portions of the bump mapped surface.

4. The method as defined in Claim 2, wherein:

rendering, from a given point of view, the lit portions of the bump mapped surface further comprises:

applying bump map data from the bump map to a perspective view of the three-dimensional graphical object;

merging the set of texture maps with the bump map data; and

displaying, from the given point of view, the perspective view of the three-dimensional graphical object on a computer display.

5. The method as defined in Claim 1, wherein each texture map includes, for one encoded radial direction in a tangent plane around each vertex of a plurality of primitives defining the surface of the three-dimensional graphical object, the smallest angle between a normal vector to the vertex and a vector from the vertex to one of the bumps on the bump mapped surface in the one radial direction.

6. The method as defined in Claim 4, wherein:

the set of texture maps comprises two texture maps each corresponding to not more than four radial directions in a tangent plane around each vertex of a plurality of primitives defining the surface of the three-dimensional graphical object; and

each said radial direction is relative to a tangent plane of a surface on the three-dimensional graphical object; and

each said radial direction is encoded in one colors channel of one said color channel.

7. A computer-readable media comprising computer-executable instructions for performing the rendering method as recited in Claim 2.

8. For a surface on a three-dimensional graphical object that is represented by a plurality of vertices in a tangent plane of the surface, where a bump map of the surface defines a bump mapped surface that includes a plurality of bumps on the bump mapped surface relative to the plurality of vertices, a method for rendering the bump mapped surface on the three-dimensional graphical object, the method comprising:

deriving a horizon map relative to the bum mapped surface for a plurality of radial directions in the tangent plane around one said vertex, wherein the derived horizon map for each of the radial directions is in a color channel of a texture map; and

repeating the horizon map derivation for each vertex of said plurality of vertices, whereby a plurality of horizon maps are derived for the bump mapped surface.

9. The method as defined in Claim 8, further comprising:

defining light having a direction relative to the tangent plane;

interpolating, relative to the direction of light, from said plurality of horizon maps for the bump mapped surface to determine those portions of the bump mapped surface that are:

lit by the defined light; and

in a shadow cast by a bump of the bump mapped surface;

rendering the bump mapped surface on the three-dimensional graphical object, from a given point of view, to depict both the lit portions of the bump mapped surface and the shadows that are cast by bumps of the bump mapped surface.

10. The method as defined in Claim 9, further comprising:

interactively receiving instructions that change the direction of light relative to the bump mapped surface; and

repeating, using the changed direction of light, the interpolating and the rendering.

11. The method as defined in Claim 8, wherein each said derivation of each of the horizon maps includes at least one of the radial directions that is:

from about zero radians to about $\Pi/2$ radians;

from about $\Pi/2$ radians to about Π radians;

from about Π radians to about $3/2\Pi$ radians; and

from about $3/2\Pi$ radians to about 2Π radians.

12 The rendering method as defined in Claim 9, wherein the interpolating further comprises determining at least two of the radial directions to the direction of light relative to the tangent plane.

13. A computer-readable media comprising computer-executable instructions for performing the method as recited in Claim 9.

14. For a surface on a three-dimensional graphical object that is represented by a plurality of vertices in a tangent plane of the surface, where a bump map of the surface defines a bump mapped surface that includes a plurality of bumps on the bump mapped surface relative to the plurality of vertices, each vertex having corresponding a horizon map for a plurality of radial directions about the vertex in the tangent plane, a method for rendering the bump mapped surface on the three-dimensional graphical object, the method comprising:

defining light having a direction relative to the tangent plane;

interpolating, relative to the direction of light, from each horizon map of each of the vertices for the bump mapped surface to determine those portions of the bump mapped surface that are:

lit by the defined light; and

in a shadow cast by a bump of the bump mapped surface;

rendering the bump mapped surface on the three-dimensional graphical object, from a given point of view, to depict both the lit portions of the bump mapped surface and the shadows that are cast by bumps of the bump mapped surface, wherein:

the horizon map for each of the vertices is stored in a texture map having a plurality of color channels; and

the corresponding horizon angle of the horizon map for each of the radial direction around each of the vertices is in a color channel of the corresponding texture map.

15. The method as defined in Claim 14, wherein each of the horizon maps includes at least one of the radial directions about each said vertex that is:

from about zero radians to about $\Pi/2$ radians;

from about $\Pi/2$ radians to about Π radians;

from about Π radians to about $3/2\Pi$ radians; and

from about $3/2\Pi$ radians to about 2Π radians.

16. The rendering method as defined in Claim 15, wherein the interpolating further comprises determining at least two of the radial directions in the corresponding horizon map to the direction of light relative to the tangent plane.

17. The method as defined in Claim 14, further comprising:

interactively receiving instructions that change the direction of light relative to the bump mapped surface; and

repeating, using the changed direction of light, the interpolating and the rendering.

18. A computer-readable media comprising computer-executable instructions for performing the method as recited in Claim 14.

19. A method comprising:

representing a surface on a three-dimensional graphical object by a plurality of polygons, each polygon having a plurality of vertices, each vertex defining a point in a tangent plane of the surface;

perturbing a vertex normal vector of the surface at each said vertex to define a plurality of bumps on the surface; and

defining in a color channel of a texture map, for each of a plurality of radial directions in the tangent plane around each said vertex, the smallest angle between the vertex normal vector and a vector from the vertex to one of the bumps in the respective radial direction.

20. The method as defined in Claim 19, further comprising:

defining light by a direction relative to:

the tangent plane of the surface; and

each said vertex normal vector;

determining, by interpolation from the color channels of the texture maps with respect to the direction of light, the portion of each said polygon that is lit by the defined light; and

rendering, from a given point of view, the portion of each said polygon that is lit by light and any other portion of each said polygon is in the shadow that is cast by the bumps on the surface in the direction of light, whereby the surface is displayed with shadows cast by bumps on the surface.

21. The method as defined in Claim 20, further comprising:

interactively receiving instructions to change the direction of light relative to the surface on the three-dimensional graphical object; and

repeating, using the changed direction of light relative to the surface on the three-dimensional graphical object, the determining and the rendering.

22. The method as defined in Claim 20, wherein the determining further comprises:

determining at least two of the radial directions in the tangent plane around the corresponding vertex of each said polygon to the direction of the light source; and

interpolating from the angle in the color channel in the text map corresponding to the at least two radial directions.

23. A computer-readable media comprising computer-executable instructions for performing the method as recited in Claim 20.

24. A method for determining shadowing cast onto a bump mapped surface by one or more bumps thereon, where the bump mapped surface is represented by a plurality of polygons each having a plurality of vertices, each vertex defining a point in a tangent plane of the bump mapped surface, where a normal vector at each said vertex is perturbed to define a bump map of the bump mapped surface that includes a plurality of bumps on the surface, the method comprising:

defining a horizon map of the surface including, for each of a plurality of radial directions in the tangent plane around each said vertex, the largest angle between the normal vector and any direct ray of light to the vertex; and

storing the horizon map as a set of texture maps corresponding to the surface on the three-dimensional graphical object.

25. The method as defined in Claim 24, further comprising:

executing an interactive program that defines a light source by a direction relative to:

the tangent plane of the surface; and

the normal of each said vertex;

determining at least two of the radial directions stored in the horizon map with respect to the direction of the light source;

interpolating from the largest angles at the at least two radial directions of the horizon map to obtain the portion of each said polygon that is in the light from the light source;

rendering the surface on the three-dimensional graphical object, from a given point of view, to include only the portion of each said polygon that is in the light from the light source;

interactively receiving instructions to change the direction of the light source relative to the surface on the three-dimensional graphical object;

repeating the determining by interpolation step using the changed direction of the light source relative to the surface on the three-dimensional graphical object; and

repeating the rendering.

26. The method as defined in Claim 24, wherein for each said vertex, each said texture map has a plurality of colors channels, each said color channel having encoded therein the largest angle between the normal vector and any direct ray of light to the vertex that does not contact any of the bumps on the surface.

27. The method as defined in Claim 26, wherein:

the set of texture maps comprises two texture maps; and

each said texture map:

corresponding to not more that four of the radial directions; and

has four colors channels each having not more than one radial direction encoding for the corresponding largest angle for each vertex between the normal vector and any direct ray of light to the vertex that does not contact any of the bumps on the surface.

28. A computer-readable media comprising computer-executable instructions for performing the method as recited in Claim 25.

29. A method for rendering a frame in a frame buffer represented by a plurality of pixels, the frame depicting a three dimensional graphical object that is defined by surfaces each having a surface geometry defined by a parameterization of a plurality of polygons, each polygon being defined by vertices, each vertex (u,v) having a bump map scalar value $F(u,v)$ defining a bump, each vertex (u,v) having a perturbed normal map vector value $N'(u,v)$ from the bump map scalar value $F(u,v)$, each vertex (u,v) having M basis maps $(B_{k=1\ \ M}(s,t))$, each vertex (u,v) having M horizon maps for each of M radial directions $(\theta_{k=1\ \ M})$ in the tangent plane of the vertex (u, v), wherein each of the M horizon maps includes the largest angle $\phi(u,v,\theta_{k=1\ \ M})$ between the perturbed normal map vector value $N'(u, v)$ and any direct ray to the vertex (u, v), the method comprising:

(i) defining a light vector (L) having a direction defined by:

the angle θ_L between the light vector (L) and the plane formed by coordinates (u,v); and

the angle ϕ_L between the light vector (L) and the perturbed normal map vector value $N'(u,v)$;

(ii) inverting a local tangent frame by $[P_u, P_v, N]^{-1} = [S^T, T^T, N^T]$ to obtain an inverted tangent frame (S,T);

(iii) taking the dot product of the light vector(L):

with the first two components of the inverted frame (S,T) to obtain the projection of the light vector (L) into the coordinate space in the tangent plane at a coordinate pair (s,t); and

with the perturbed normal map vector value $N'(u, v)$ at the vertex to obtain cosine (ϕ_L);

(iv) setting the camera angle of the rendering to a point of view to be rendered for the frame to write into the space of a texture map;

(v) computing first and second texture effects on each pixel in the frame buffer, respectively, from first and second sets of the M directions stored as texture maps, wherein each said largest angle $\phi(u,v,\theta_k)$ is in one of a plurality of color channels of a texture map, wherein one of the M directions corresponds to each said color channel of the texture map, and wherein the first and second texture effects are defined, respectively by:

a basis map $B_1(s, t)$ of said M basis maps $(B_{k=1..M}(s, t))$, and a horizon map, $\phi_1(u, v)$ of said M horizon maps; and

a basis map $B_2(s, t)$ of said M basis maps $(B_{k=1..M}(s, t))$, and a horizon map, $\phi_2(u, v)$ of said M horizon maps;

(vi) storing the first and second texture effects for each pixel in the frame buffer in a texture map $\phi(\theta_{LIGHT})$;

(vii) for a given camera perspective view:

on a first operation, rendering a model of the three dimensional graphical object with an ambient low level lighting term only;

on a second operation:

setting an alpha test and a stencil function to accept only those pixels in the frame buffer that have a non-zero alpha test result;

setting a color mask upon the frame buffer, wherein the color mask will not write to the color channels of the

texture maps, whereby the ambient low level lighting term previously rendered is preserved;

drawing, using multi-texturing, for the angle (ϕ_L) and the angle to the horizon (θ_L), the first and second texture effects on each pixel in the frame buffer, which are, respectively, cosine(ϕ_L) that is greater than ϕ_L, and $\phi(\theta_{LIGHT})$;

on a third operation:

setting the alpha test off;

setting the color mask upon the frame buffer to allow writing to the color channels of the texture maps;

setting the stencil function to only draw pixels in the frame buffer that have a non-zero alpha test result;

setting a blending function to accumulate into the frame buffer with the ambient low level lighting term;

drawing the vector valued perturbed normal map $N'(u,v)$; and

displaying the three dimensional graphical object defined by pixels in the frame buffer, wherein the displayed object has an ambient only term in shadowed regions and normal bump mapping in non-shadowed regions.

30. The method as defined in Claim 29, further comprising:

interactively receiving instructions that change the definition of the light vector (L) with respect to each vertex (u,v); and

repeating (i) through (vii) using the changed definition of the light vector (L).

31. A system comprising:

a memory to store:

a frame buffer including a plurality of pixels in a representation of a three-dimensional graphical object;

a bump map of a bump mapped surface on the three-dimensional graphical object; and

a plurality of texture maps, corresponding to a plurality of horizon maps of the bump mapped surface, for reuse in rendering the three-dimensional graphical object;

a display device;

a processor, coupled to the display device and the memory, to process each said pixel to produce on the display device a rendering of the bump mapped surface with shadows cast, as a function of the plurality of horizon maps, by light impinging upon bumps on the bump mapped surface.

32. The system as defined in Claim 31, wherein:

each said texture map has red, green, blue, and alpha color channels; and

each said color channel has encoded therein a representation of at least one radial direction of the corresponding horizon map for one point on the bump mapped surface.

33. The system as defined in Claim 31, further comprising an input device, coupled to the processing unit, to communication an interactive instruction to the processor that changes the direction of light relative to the bump mapped surface.

34. A processing system comprising:

a database having a first set of data representing a bump map for the bumpmapped surface and second set of data corresponding to horizon map of the bump mapped surface, wherein the second set of data is stored in color channels of a texture map for reuse in rendering a three-dimensional graphical object;

a processor operatively connected to receive the first and second sets of data and including a logic element implemented as hardware that:

interpolates light in a direction with respect to the horizon map; and

determines from the interpolated light direction pixels that are representative of a rendering of the bump mapped surface on the three-dimensional graphical object that are shadowed by light cast upon bumps on the bump mapped surface;

an input device, coupled to the processor, for interactively inputting instructions to the processor that change the direction of light relative to the bump mapped surface.

35. The processing system as defined in Claim 34, wherein the processor generates a display signal:

incorporating for display those pixels that are lit by light in the direction with respect to the horizon map; and

does not incorporating for display those pixels that are in shadowed by light cast upon the bumps on the bump mapped surface.

36. Computer executable media comprising:

a bump map of a bump mapped surface on a three-dimensional graphical object; and

a plurality of texture maps including a plurality of horizon maps of the bump mapped surface.

37. The computer executable media as defined in Claim 36, further comprising a first code segment that, when executed by a computer:

defines light having a direction relative to the bump mapped surface;

interpolates, from the plurality of horizon maps relative to the direction of light, to determine those portions of the bump mapped surface that are lit by the defined light; and

renders, from a given point of view, the bump mapped surface upon a display device:

those portions of the bump mapped surface that are lit by the defined light; and

shadows cast upon the bump mapped surface by the defined light interfering with bumps on the bump mapped surface.

38. The computer executable media as defined in Claim 37, further comprising a second code segment that, when executed by a computer:

interactively receives instructions from an input device that change the direction of light relative to the bump mapped surface; and

repeats, using the changed direction of light, the interpolates and the renders.

39. A data structure stored on a computer-readable medium, the data structure comprising:

a first collection of texture maps each defining, in a plurality of color channels, a bump map describing a bump mapped surface on a three-dimensional graphical object; and

a second collection of texture maps each defining, in a plurality of color channels, a horizon map for the bump mapped surface, wherein each said color channel corresponds to a radial direction about a point on the bump mapped surface.

40. The data structure as defined in Claim 39, further comprising other texture maps defining in color channels thereof other textures of the bump mapped surface.

41. A data structure stored on a computer-readable medium, the data structure comprising:

a first set of data representing a plurality of polygons representative of a surface on a three dimensional graphical object;

a second set of data representing a bump map of the surface defining a bump mapped surface as a function of the vertices corresponding to the plurality of polygons; and

a third set of data representing, for each vertex of each polygon, a horizon map stored as a plurality of texture maps each corresponding to a plurality of radial directions of the horizon map, wherein:

each of the texture maps has a plurality of colors channels; and

each of the color channels corresponds to the horizon angle of one of the radial directions of the horizon map relative to the tangent plane of the one of the vertices.